Helena Area Ground Water Project

Lewis & Clark Water Quality Projection District

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October 2010

ABSTRACT

The Lewis & Clark Water Quality Protection District (LCWQPD) began implementation of a long-term ground water monitoring program in the Fall of 2009. The program included semi-annual sampling from 25 wells in the LCWQPD Monitoring Well network, which includes 9 single wells and 8 nested well sets (16 total wells), and from 5 residential wells where historical data is present. The nested wells provide information on changes in ground water chemistry with depth. ***The goal of the project is to characterize the current ground water quality across the Helena Valley, with an emphasis on identifying nutrient levels in ground water***. The nutrient data represents the initial effort to characterize the impacts of non-point pollutant sources, primarily agriculture and septic systems, to ground water quality. In the Helena Valley, all surface and ground water discharges through Lake Helena, and the ground water data will be used to estimate water quality impacts from nutrients to Lake Helena from ground water recharge. Additionally, the current data can be compared to historical data to evaluate changes in water quality, as well as provide baseline data for comparison with the results from future sampling events. The second component of the sampling and analysis program incorporated monthly sampling at the five residential wells to assess seasonal trends.

The nutrient data from the two semi-annual sampling events show nitrate concentrations ranging from less than 0.01 mg/L up to 13.7 mg/L, with a median value of 1.71 mg/L. Ammonia was detected at 0.07 mg/L at the location where nitrate was not detected during both sampling events. Total phosphorus concentrations ranged from 0.01 mg/L to 1.57 mg/L, with a median of 0.03 mg/L. Arsenic was detected in approximately half of the samples, with detected concentrations ranging from 0.003 mg/L up to 0.020 mg/L, with samples from 5 wells exceeding the drinking water standard of 0.010 mg/L. The poster will present the major ion chemistry data using stiff diagrams, as well as the results of the monthly sampling program.

Data Types and Assessment Methods

Question – Has the quality of local ground water, as a potable water source in Helena Valley, been impacted by agriculture and/or growth and development??

WATER QUALITY

Assessment Methods – Compare available water quality data (4 sampling events) at LCWQPD Monitoring Well network in Helena Valley

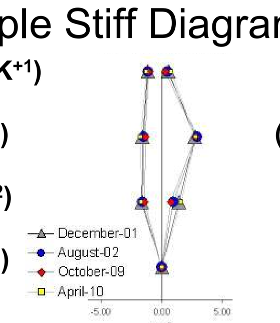
Older data - November 2001, August 2002 (After Well Installation)

Current data - October 2009, April 2010 (Current Project)

Approach – Use stiff diagrams to compare chemistry of the primary dissolved constituents and total dissolved solids for waters. Compare nutrients and trace metals with drinking water standards, and with general changes between Older and Current sampling results

Sample Stiff Diagram

Sodium&Potassium	(Na^{+1}+K^{+1})		(Cl^{-})	Chlorine
Calcium	(Ca^{+2})		(HCO_3^{-})	Bicarbonate
Magnesium	(Mg^{+2})		(SO_4^{-2})	Sulfate
Iron	(Fe^{+3})		(CO_3^{-2})	Carbonate



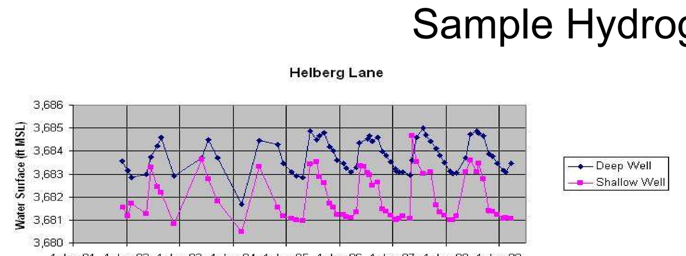
Stiff diagrams show the relative proportions of the most common chemical ions dissolved in waters. The diagram shape provides a visual comparison of chemistry (points) and total dissolved solids (total size of shape) between waters. Diagrams show data from 4 sampling events, with newer data layered over older data

WATER QUANTITY AND GROUND WATER DEPLETION

Assessment Methods – Hydrograph assessment of water level changes from private wells and LCWQPD Monitoring Well network in the Helena area. Compare with precipitation patterns

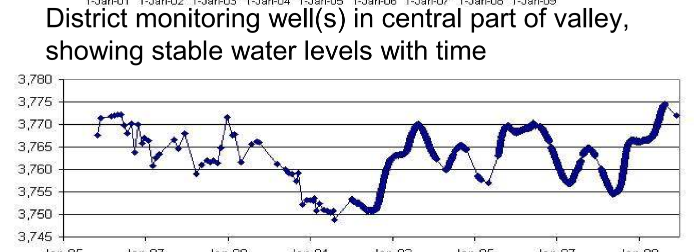
Approach – Develop and compile hydrographs, compare with precipitation data as potential recharge, group areas with like hydrographs.

Sample Hydrographs

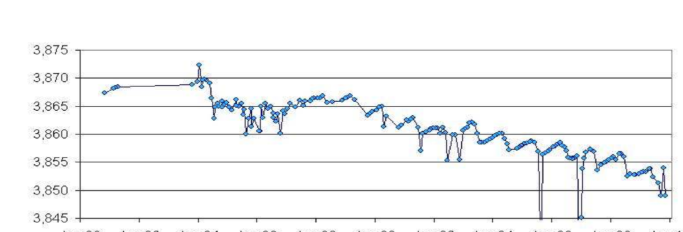


District monitoring well(s) in central part of valley, showing stable water levels with time

Hydrographs show changes in the ground water surface elevation with time. Levels fluctuate naturally, with spring recharge followed by declining water levels. Hydrograph patterns provide information on long-term changes in conditions within the aquifer

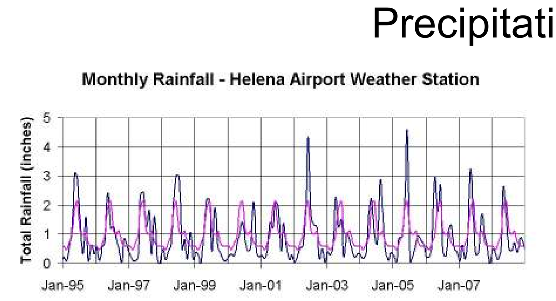


Private well water level, showing response to recharge from stream loss. Low period from drought in 2000-2002 period

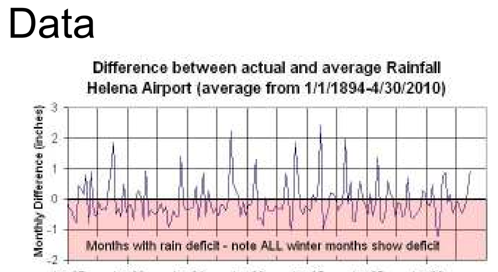


Monitoring well at Department of State Lands in central part of North Hills, showing ground water depletion

Precipitation Data

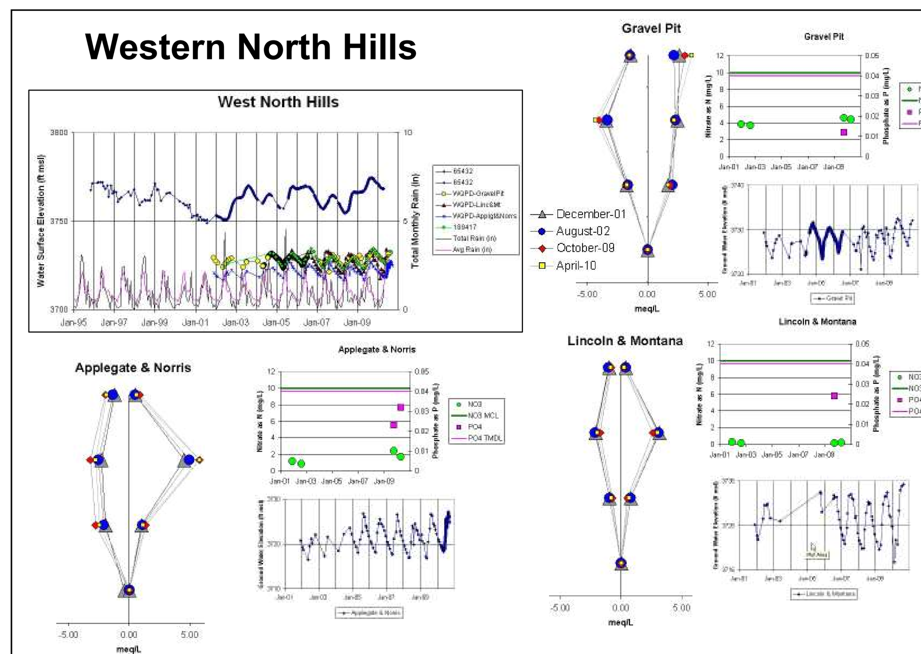


Monthly precipitation totals compared with monthly averages from Helena Airport; average data from 1/1/1894 to 4/30/2010. Note drought conditions in 2000



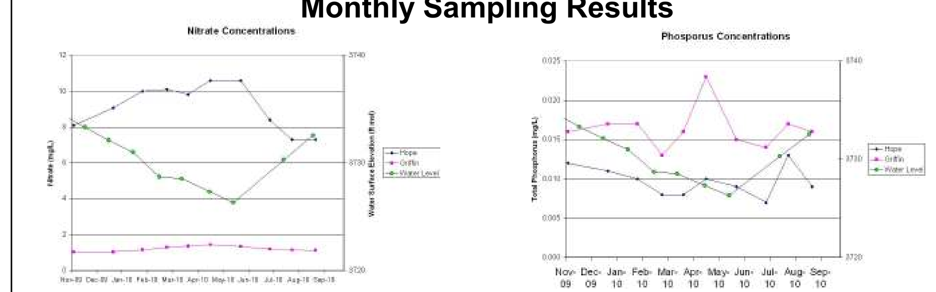
The difference between actual monthly and average monthly totals. General trend shows variability of monthly precipitation compared with average. A deficit, compared to average, is visible for winter months during most years

Western North Hills



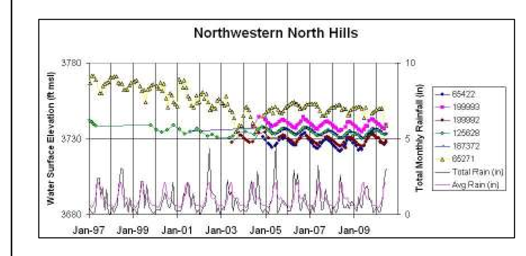
Western North Hills – Water quality results are generally stable. Ground water levels are generally stable with similar recharge/response patterns reflecting seasonsl precipitation patterns

Monthly Sampling Results



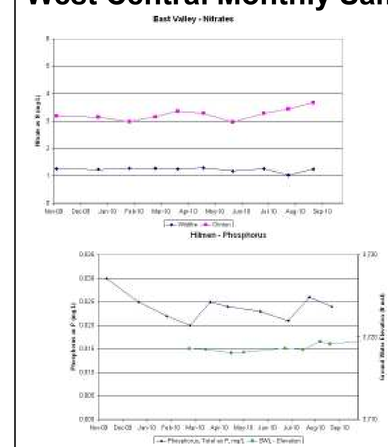
Monthly water quality results for nitrate and phosphate show similar patterns, with highest concentrations during winter/spring water level low periods, with lower concentrations as water levels increase with spring recharge

Northwestern North Hills



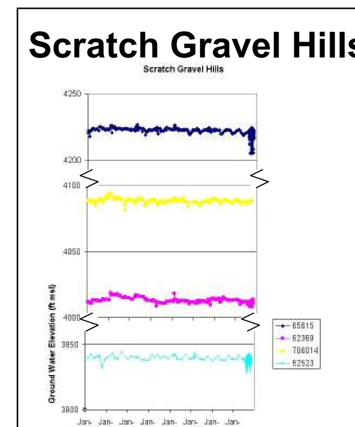
Northwestern North Hills – Ground water levels are generally stable with similar recharge/response patterns; however, the well(s) with longer records show apparent decline.

West Central Monthly Sampling



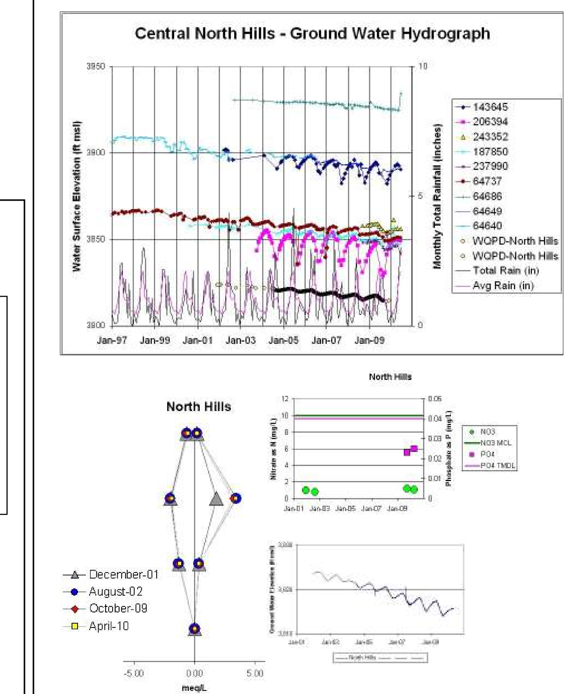
Water quality and levels appears consistent over time with little seasonal change

Scratch Gravel Hills



Water levels appear generally consistent

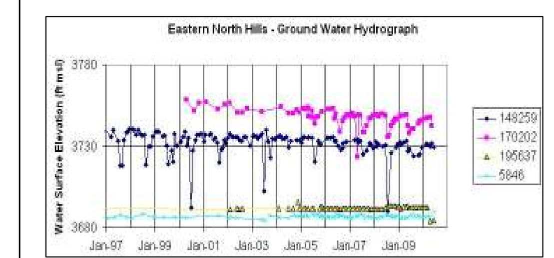
Central North Hills



Central North Hills – Water quality appears consistent over time from single monitoring location

Ground water levels show a consistent decline in both seasonal high and low levels – visible in a number of wells in the area.

Eastern North Hills



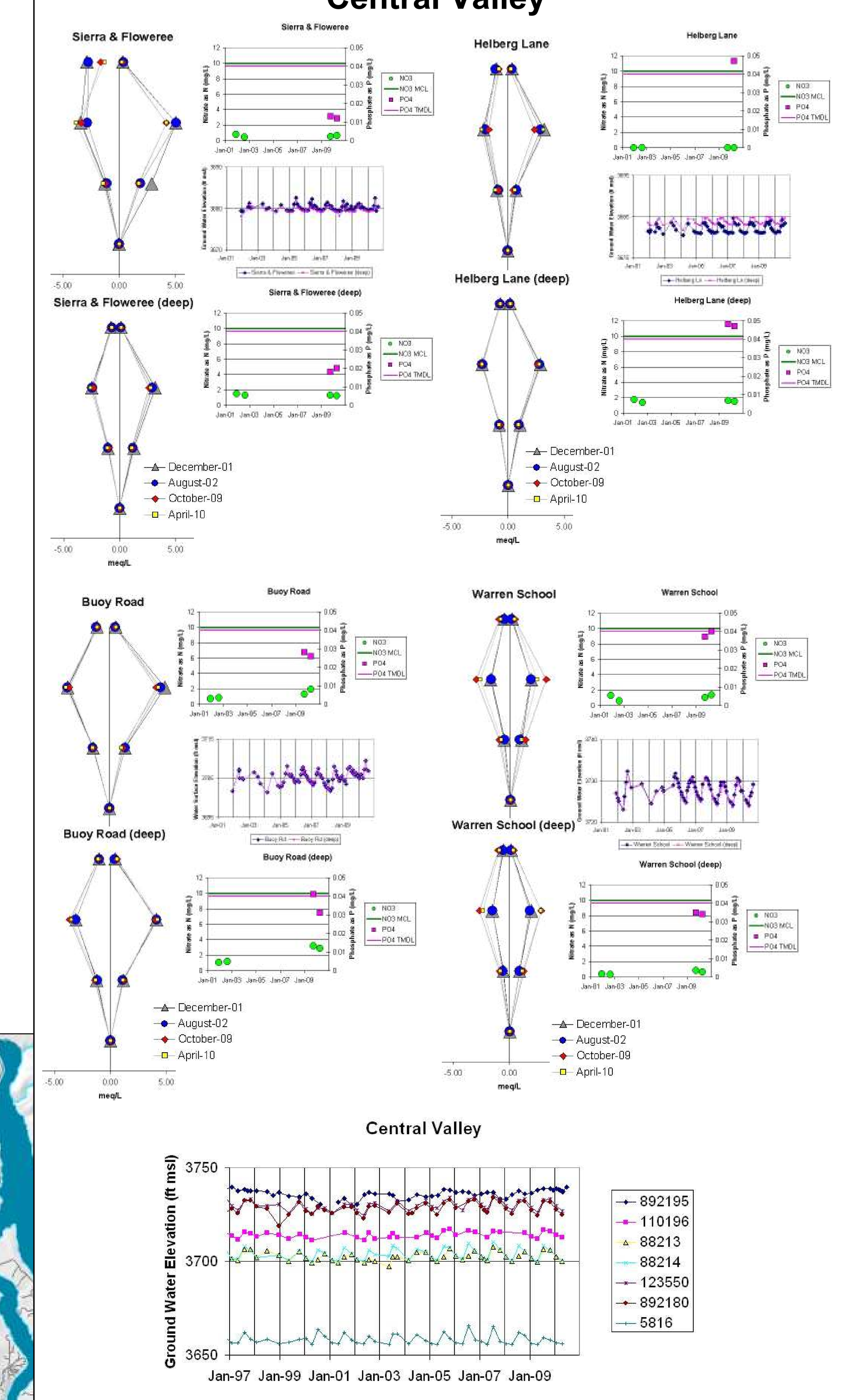
Eastern North Hills – Wells in north central part of valley, inside Helena Irrigation Canal, show stable water levels with little fluctuation.

Bedrock well north of east side of Lake Helena shows declining water levels over time

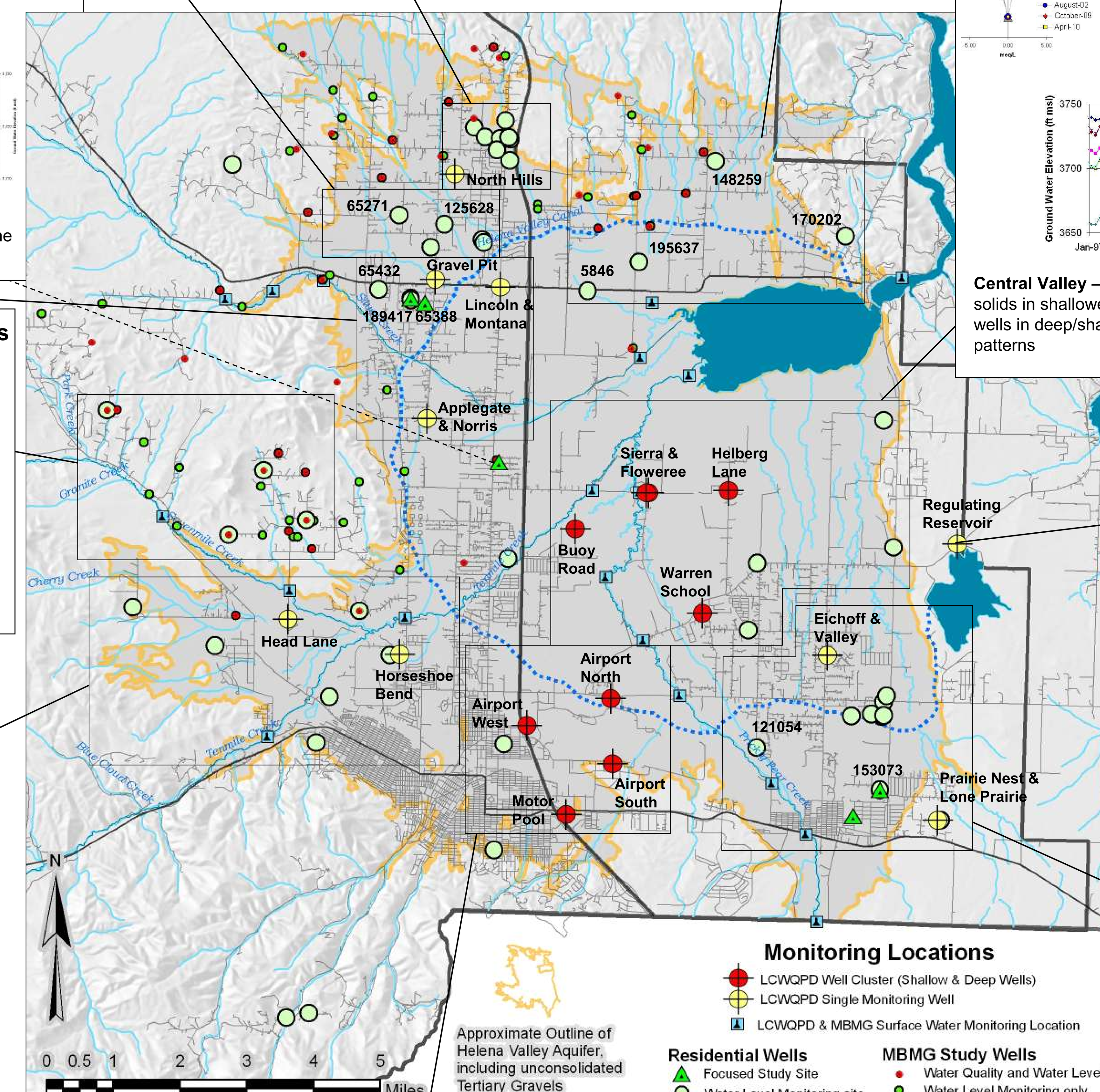
Additional well in northern part of area also shows a decline in water levels.

Deep wells in this area are characterized by warm water (discussed elsewhere)

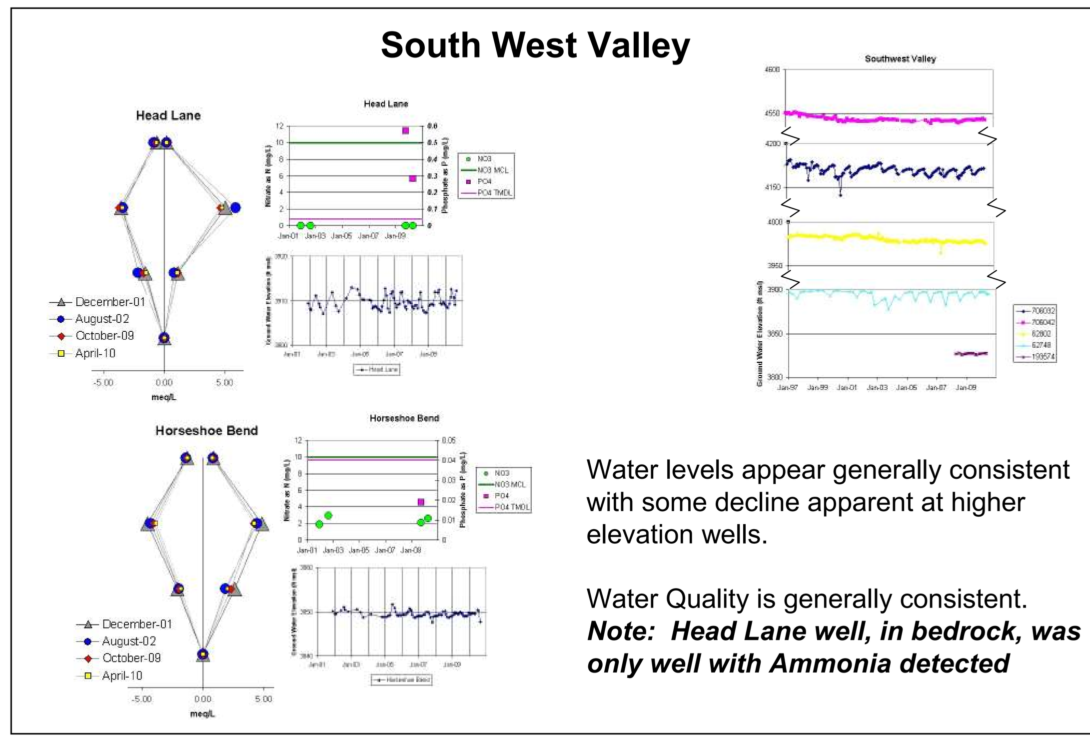
Central Valley



Central Valley – Water quality is generally stable, with more dissolved solids in shallower wells; hydrographs show stable water levels, with wells in deep/shallow clusters showing similar recharge/response patterns



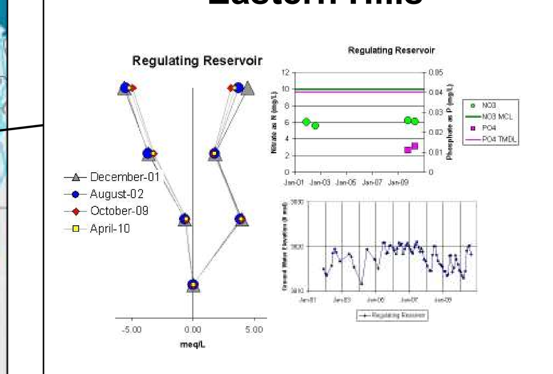
South West Valley



Water levels appear generally consistent with some decline apparent at higher elevation wells.

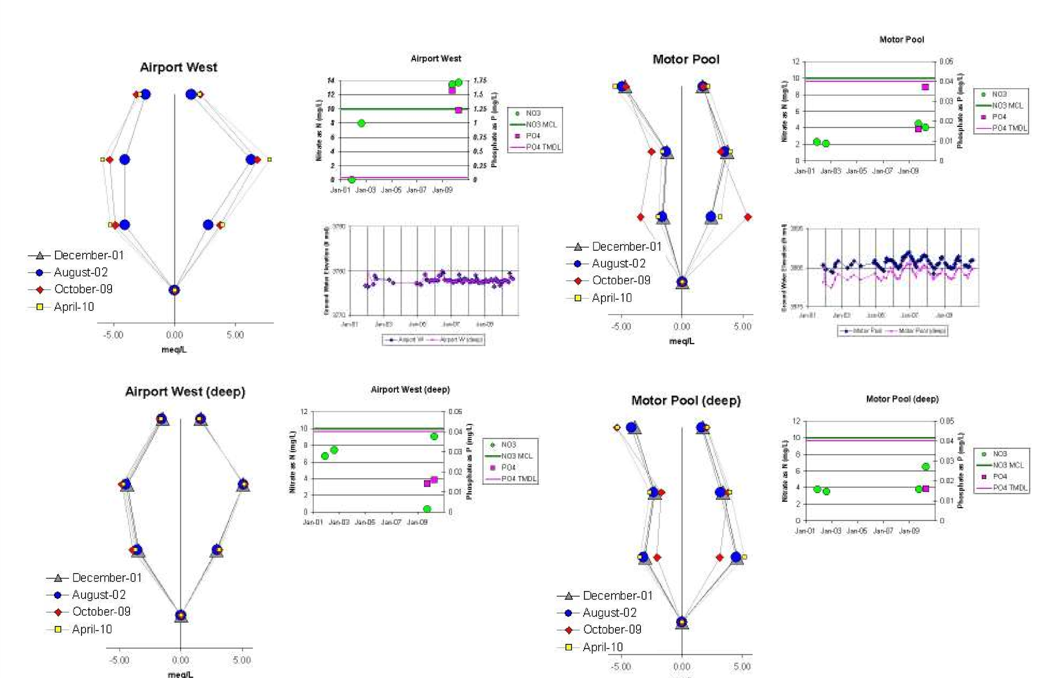
Water Quality is generally consistent. ***Note: Head Lane well, in bedrock, was only well with Ammonia detected***

Eastern Hills



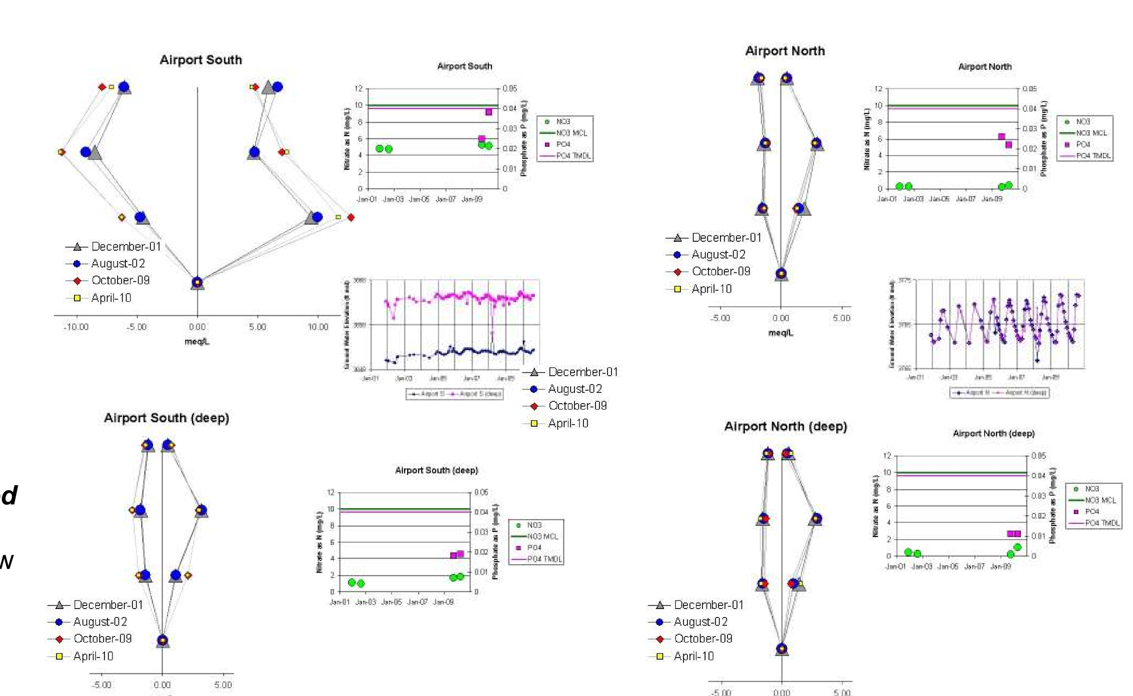
Single well near regulating reservoir, with seasonal recharge linked to lake and/or agricultural irrigation practices adjacent to well. Water quality generally different than other sites in well network, possibly to screened interval in Tertiary sediments.

South Central Valley

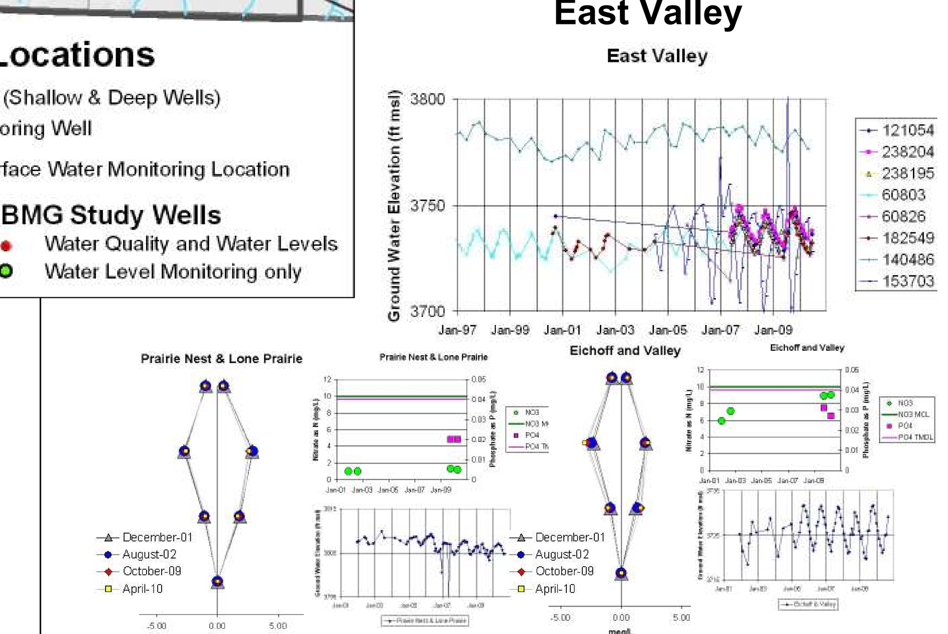


Well clusters show that water levels appear generally consistent with an upward vertical gradient at the Airport South location.

Water Quality varies between locations, and shallower wells generally show more dissolved consituents. ***Very high nitrate and phosphate levels detected in shallow ground water at Airport West location.*** Shallow water south of airport also has elevated levels of dissolved constituents.

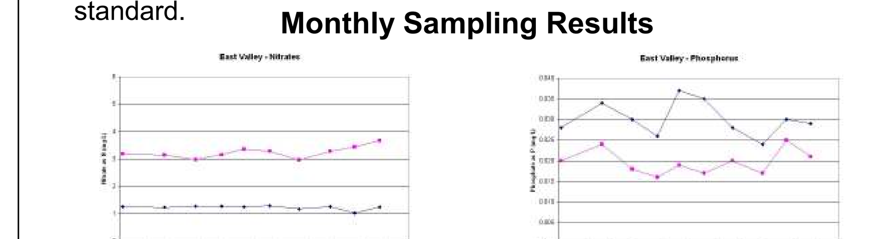


East Valley



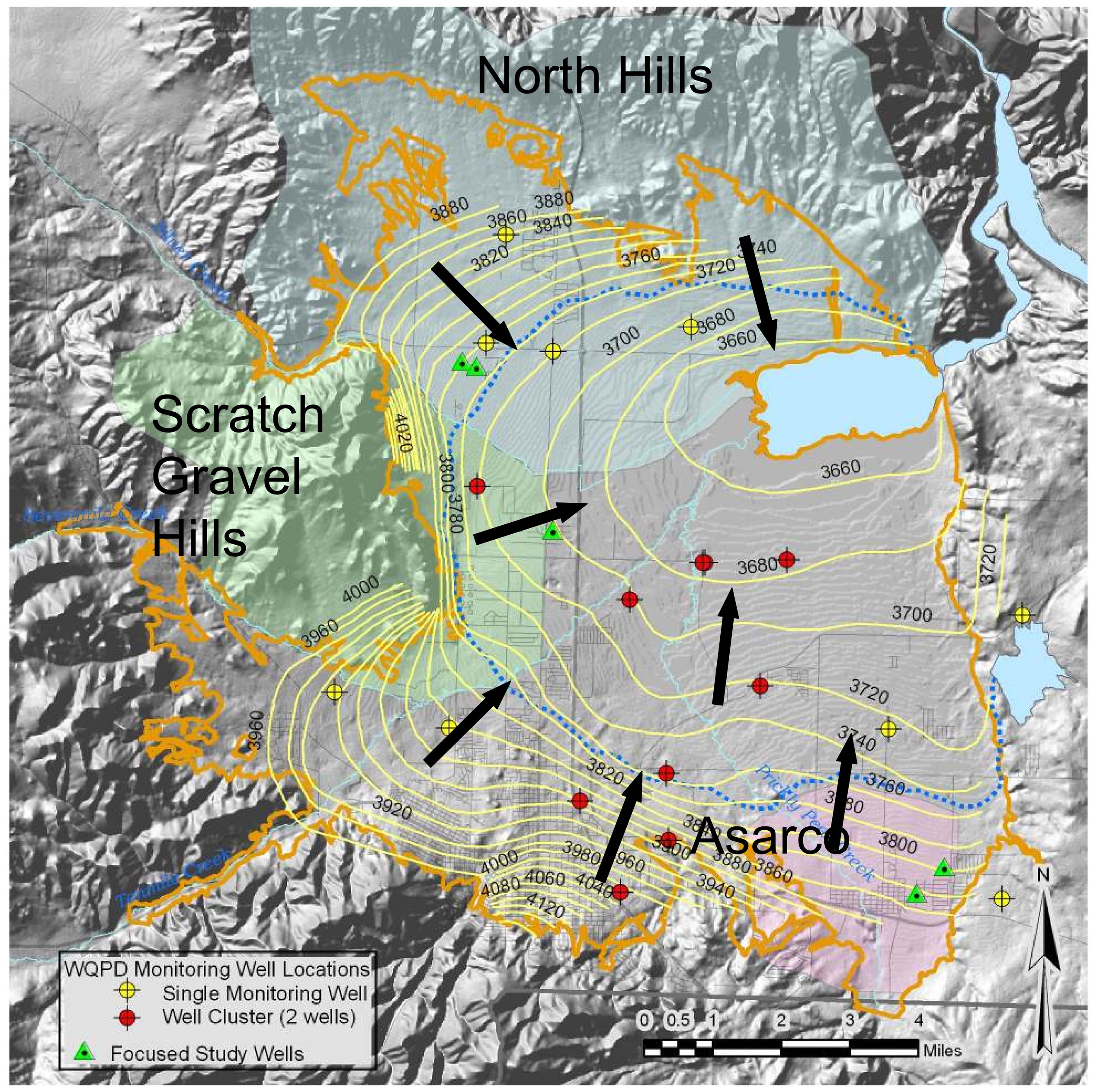
Water levels are generally consistent, with variable seasonal response Water quality appears generally consistent over time; however, nitrate levels at Eichoff & Valley well are currently near drinking water standard.

Monthly Sampling Results



Monthly water quality results for nitrate and phosphate show similar patterns, with highest concentrations during winter/spring and late summer low water level periods. Hydrograph for well shows high variability from pumping in area and not considered representative of area

Helena Valley Hydrogeology



Helena valley aquifer comprised of coarse-grained alluvial deposits where streams enter valleys, with decreasing grain size away from coarse areas to central part of valley, where finer-grained facies dominate and flow occurs in thinner, less frequent coarser lenses. In central part of the valley, surface flowing artesian conditions occur at depth.

All ground water flows towards Lake Helena as a discharge point to the combined surface/ground water system. Shallow ground water, less than 10 feet below ground surface, is present across much of the central part of the valley

Water balance provides method to evaluate recharge to aquifer. Primary recharge occurs from stream loss, direct infiltration of precipitation, and from underlying bedrock aquifer system

Conceptual Model derived from published USGS Documents as primary information sources:

- Thamke, J.N. and Reynolds, M.W., 2000, Hydrology of the Helena area bedrock, west-central Montana, 1993-98; with a section on geologic setting and a generalized bedrock geologic map: U.S. Geological Survey Water-Resources Investigations Report 00-4212, 3 plates.
- Kendy, Eloise, Olsen, Bill, and Malloy, John C., 1997, Field screening of water quality, bottom sediment, and biota associated with irrigation drainage in the Helena Valley, west-central Montana, 1995: U.S. Geological Survey Water-Resources Investigations Report 97-4214, 62 p.
- Briar, D.W., and Madison, J.P., 1992, Hydrogeology of the Helena valley-fill aquifer system, west-central Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4023, 92 p.
- Moreland, J.A., and Leonard, R.B., 1980, Evaluation of shallow aquifers in the Helena Valley, Lewis and Clark County, Montana: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1101, 24 p.
- Moreland, J.A., Leonard, R.B., Reed, T.E., Clausen, R.O., and Wood,W.A., 1979, Hydrologic data from selected wells in the Helena Valley, Lewis and Clark County, Montana: U.S. Geological Survey Open-File Report 79-1676, 54 p.
- Wilke, K.R., and Coffin, D.L., 1973, Appraisal of the quality of ground water in the Helena Valley, Montana: U.S. Geological Survey Water-Resources Investigations Report 32-73, 31 p. Lorenz, H.W., and Swenson, F.A.,
- 1951, Geology and ground-water resources of the Helena Valley, Montana, with a section on The chemical quality of the water, by H.A. Swenson: U.S. Geological Survey Circular 83, 68 p.

Potentiometric surface map for Helena Valley Aquifer, with 20-foot contour interval from numerical Flow model of system (Briar & Madison, 1992). MBMG North Hills and Scratch Gravel sites, and Asarco Study Areas are shown.

Water Balance

Developed from numerical flow model of system presented in Briar & Madison, 1992.
System shows recharge surplus during spring runoff and summer, with a decrease in storage in winter months

Components of Water Budget

Ground-Water Recharge and Discharge

Recharge to and discharge from the Helena valley-fill aquifer system can be derived from the following equation:

$$LS\_in + LC\_in + IF\_in + PN\_in + BR\_in = SD\_out + LH\_out + WL\_out \quad (1)$$

where:

- LS_in = Recharge from infiltration of streamflow,
- LC_in = Recharge from infiltration of water in irrigation canals,
- IF_in = Recharge from infiltration of excess water applied to irrigated fields (applied irrigation water plus precipitation on irrigated fields minus evapotranspiration),
- PN_in = Recharge from infiltration of precipitation on non-irrigated areas (precipitation minus evaporation during the non-growing season; precipitation minus evapotranspiration during the growing season),
- BR_in = Recharge from inflow from bedrock,
- SD_out = Discharge through leakage to streams and drains,
- LH_out = Discharge through upward leakage to Lake Helena, and
- WL_out = Discharge through withdrawals from wells.

Water Budget Volume Estimates

Table 4.--*Estimated water budget for the valley-fill aquifer system*

	Acre-feet												
	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Annual (rounded)
Recharge													
LS_in	1,100	1,140	1,100	1,140	1,140	920	1,090	1,060	1,090	1,080	980	1,100	12,900
LC_in	270	1,410	1,370	1,410	1,410	1,140	46	0	0	0	0	0	7,060
IF_in	-480	8,970	9,070	10,600	3,180	-4,230	-76	0	0	0	0	0	27,000
PN_in	0	0	0	0	0	0	0	0	0	0	0	0	0
BR_in	3,270	3,380	3,270	3,380	3,380	3,270	3,380	3,270	3,380	3,380	3,050	3,380	39,800
Total (rounded)	4,160	14,900	14,800	16,500	9,110	1,110	4,440	4,330	4,470	4,460	4,030	4,480	86,800
Discharge													
SD_out	2,980	3,070	2,980	3,070	3,070	2,980	3,070	2,980	3,070	3,070	2,780	3,070	36,200
LH_out	4,110	4,250	4,110	4,250	4,250	4,110	4,250	4,110	4,250	4,250	3,840	4,250	50,000
WL_out	72	282	427	634	225	69	68	66	68	68	61	68	2,110
Total (rounded)	7,160	7,600	7,520	7,950	7,540	7,160	7,390	7,160	7,390	7,390	6,680	7,400	88,300

Water Budget Balance

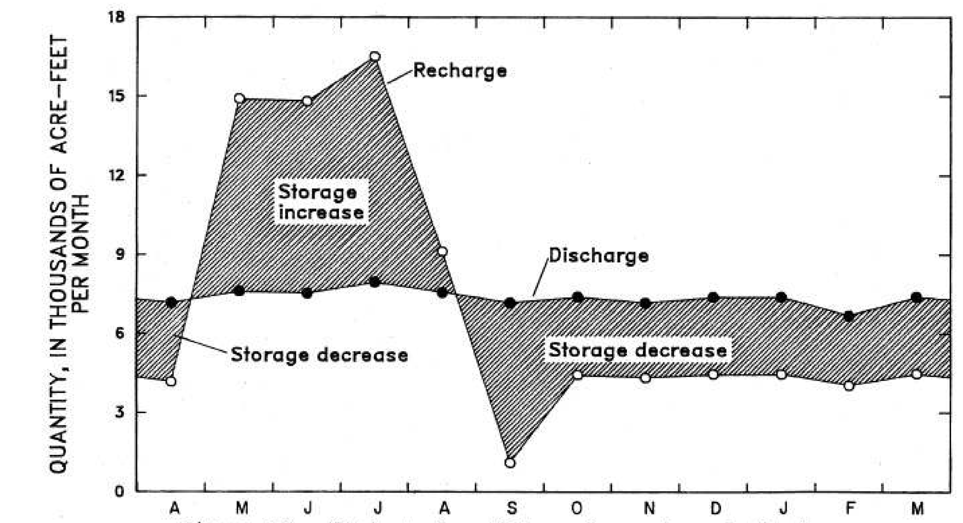


Figure 10.--Estimated monthly recharge to and discharge from the valley-fill aquifer system.

Significant Report Conclusions

Bedrock flow is a significant component of recharge to the alluvial aquifer system, as quoted from the report:

> "The direction of ground-water flow and mass balance analysis indicate that recharge through inflow from fractures in the surrounding pre-Tertiary bedrock (BR_in) is a significant part of the total recharge entering the valley-fill aquifer system. However, flow from bedrock is almost impossible to measure directly…"

The bedrock system provides potentially significant storage for the alluvial system, as evidenced by a water balance of precipitation and surface runoff in the Prickly Pear Creek watershed, as quoted from the report:

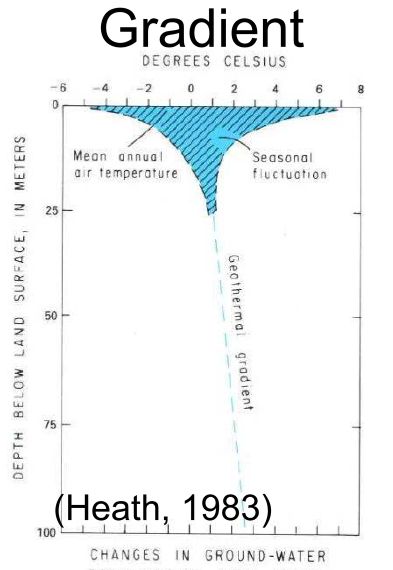
> "Evidence of storage in the bedrock flow system adequate to supply sustained recharge to the valley-fill aquifer also can be Inferred from a mass balance analysis of tributary basins. GIS analysis of lines of equal precipitation in the Prickly Pear drainage basin indicates that about 235,000 acre-ft of precipitation falls in the drainage annually. In contrast, the estimated; long-term mean annual flow of Prickly Pear Creek at th eproject site 09N02W07BCAA01 is only 48,000 acre-ft. Whereas most of the difference between precipitation input and surface-water outflow is due to evapotranspiration and other consumptive in the Prickly Pear drainage basin, some of the difference is due to precipitation that infiltrates the bedrock flow system."

Ground Water Temperature

Sample Data - Temperature in monitoring wells – up to 17C (Airport, Lincoln & Montana)

Background - Average water temperature1-2°C above mean annual temperature
Can seasonally fluctuate several degrees near surface
Ground water temperature increases with depth at *Geothermal Gradient*
- 1.8°C/100 m (0.0055°C/ft) in "normal" sedimentary basins
- 3.6°C/100 m (0.011°C/ft) in volcanic areas (Heath, 1983)

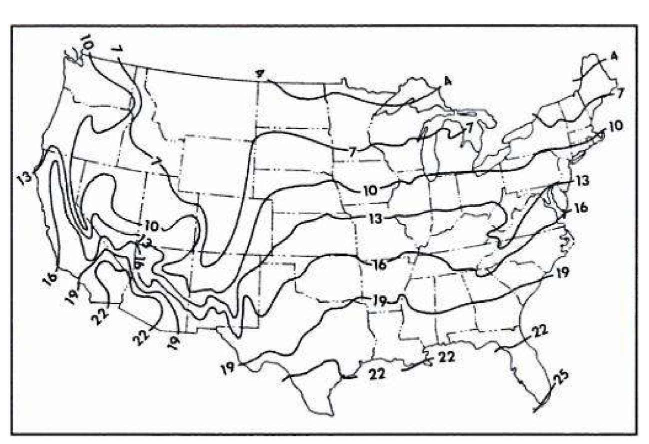
Geothermal Gradient



(Heath, 1983)

Average Ground Water Temperature

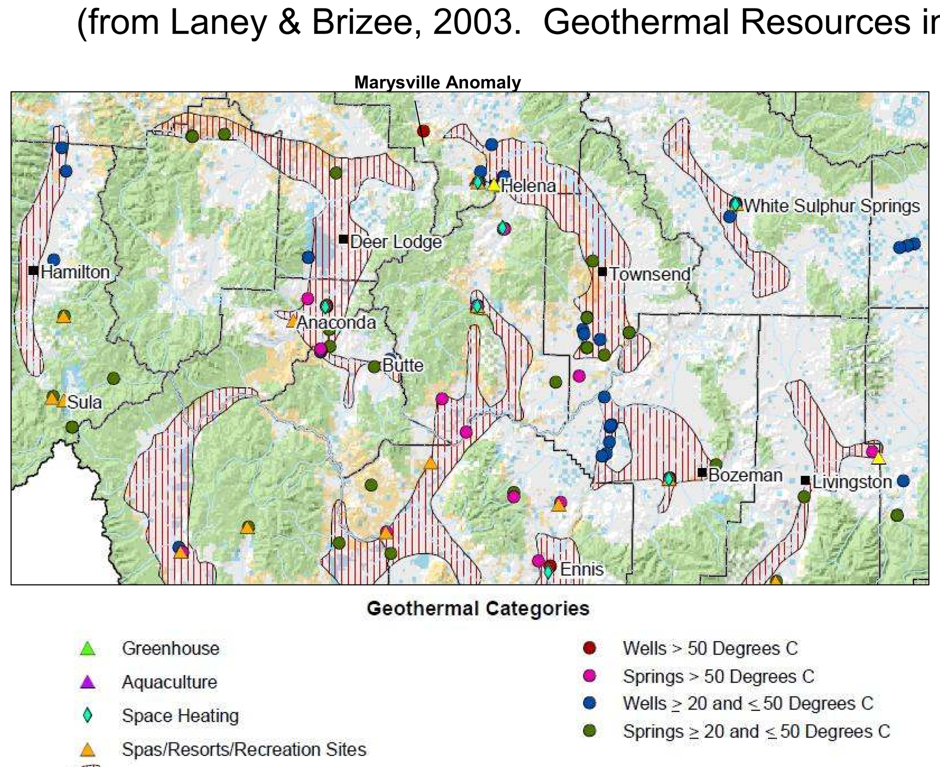
Based on Climate - Mean Annual Temperature (Heath, 1983)
Applies to shallow, locally recharged ground water systems



Helena, Montana
Average shallow ground water temperature should be between 4 and 7°C, and increase at geothermal gradient with depth

Geothermal Resources in Southwest Montana

(from Laney & Brizee, 2003. Geothermal Resources in Montana)

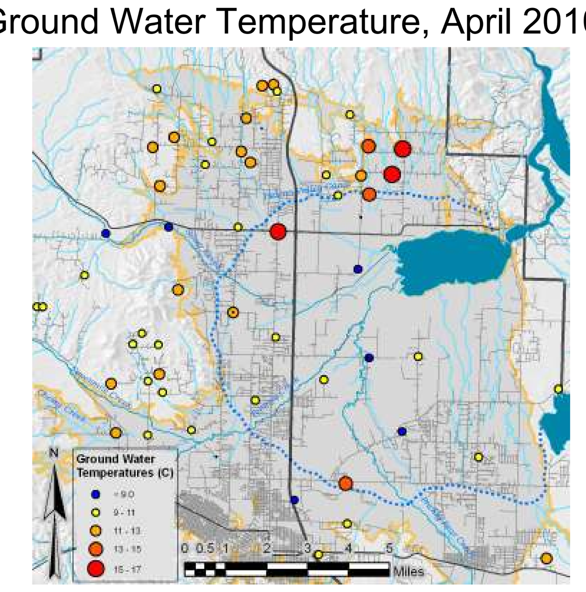


Hot Springs
Water heated at depth from geothermal gradient to boiling point, thermal expansion and heat bring water towards surface along faults/fractures

Helena Area Hot Springs
Broadwater Hot Springs
SW Helena Valley
Marysville Thermal Anomaly
NW of Helena, near continental divide

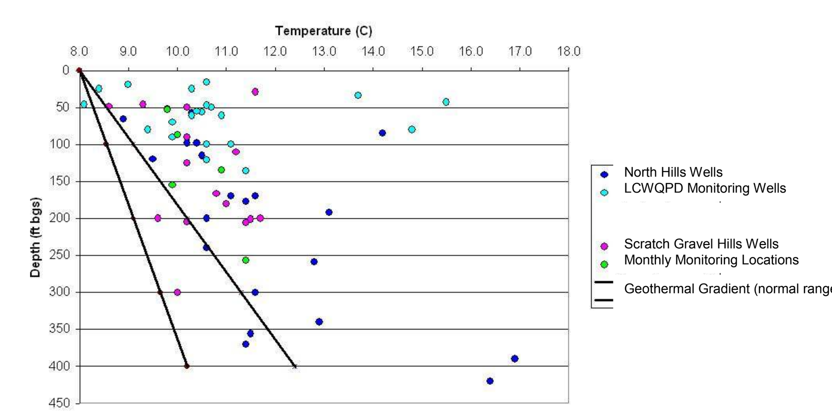
Note: Geothermal wellsare developed in the Helena Valley to depths of several thousand feed.

Ground Water Temperature, April 2010



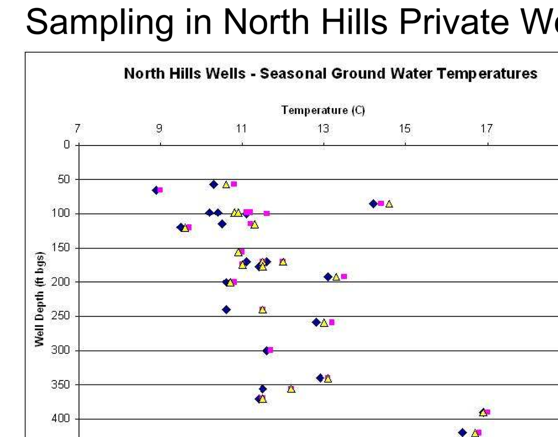
Map showing ground water temperatures from sampling in April 2010. This time of year should reflect coldest conditions from snowmelt recharge. Note warm water in north hills wells.

Ground Water Temperature compared to depth of total well, April 2010



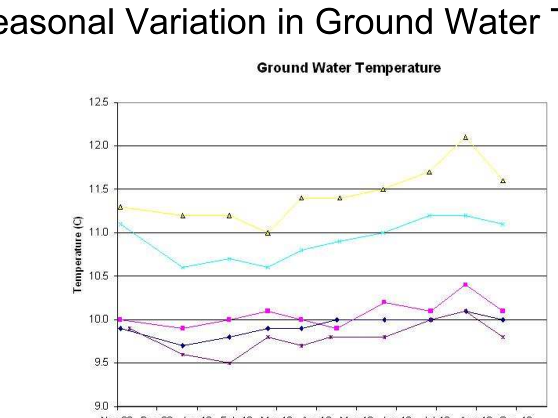
Ground water temperature compared to total depth of well from samples collected across valley. Geothermal gradient is shown. Note points well away from geothermal gradient lines.

Ground Water Temperature from Seasonal Sampling in North Hills Private Wells



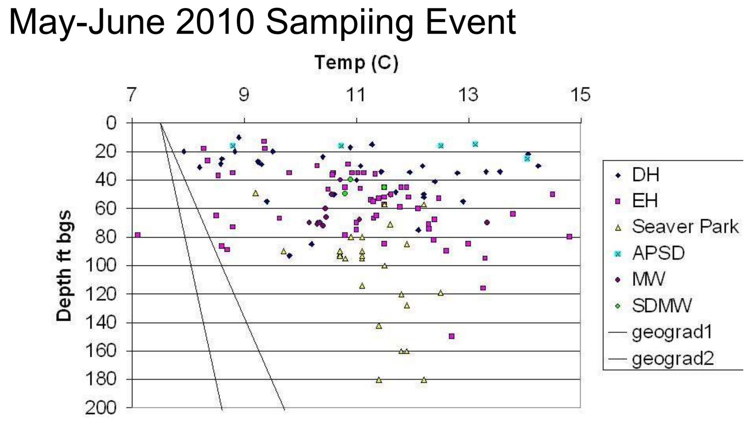
Ground water temperature from 3 sampling events (April, August & October). Note general stability of warm temperatures in different events, with more variability in shallower wells.

Seasonal Variation in Ground Water Temperature



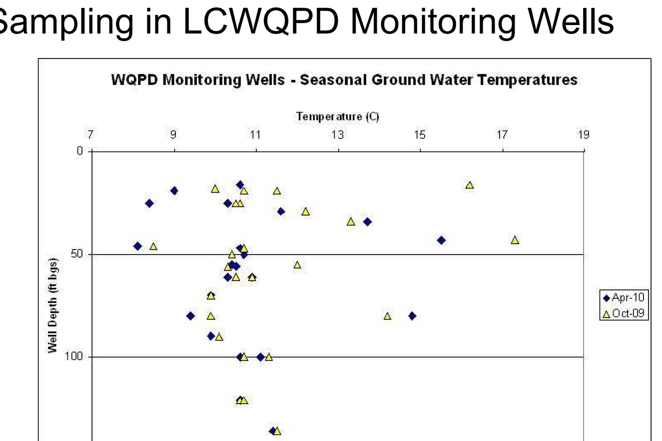
Fluctuations in ground water temperature from wells sampled on regular monthly intervals. The temperature variation in these wells is generally at or less than 1 C

Ground Water Temperature compared to depth of total well, East Helena ASARCO site May-June 2010 Sampiing Event



Ground water temperature compared to total depth of well from samples at Asarco near East Helena, in southern part of valley

Ground Water Temperature from Seasonal Sampling in LCWQPD Monitoring Wells



Ground water temperature from 3 sampling events (April, October). Note general stability of warm temperatures in different events, with much greater variability in shallower wells.

Significance of Temperature and Water Balance Data

There is a high geothermal gradient in the Helena Valley. Warm water may be indicative of recharge from bedrock system to shallow alluvial system. Warm recharge mixing with shallower local recharge will result in intermediate temperatures above expected.

Temperature may represent a method of quantifying the recharge from the bedrock system to the shallow aquifer system, but further work is needed.

Ongoing Studies

Helena Valley Ground Water Project will continue with sampling at selected locations. Program will include:
Semi-Annual ground water sampling
Nitrogen and Oxygen isotope sampling of ground water to evaluate potential sources to system
Installation of shallow piezometers for evaluation of surface and ground water interaction

The Lewis & Clark Water Quality Protection District works with MBMG for implementation of the focused studies in the North Hills and Scratch Gravel Hills area. The district also has coordinated with the project team for the former Asarco site in East Helena
District staff are incorporated the data from these studies to characterize water resources across the valley and area.